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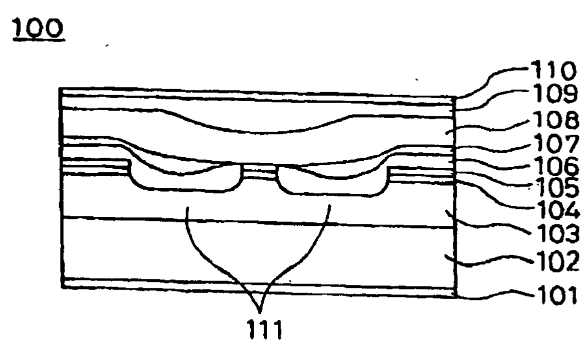
(54) Semiconductor laser

(57) The object of the present invention to provide a semiconductor laser that can be fabricated on a GaAs substrate and that has an oscillation region in the 1.3-micron band and thus the semiconductor laser of the present invention has a quantum well layer made of GaAsSb in an active region, this active region being provided on a GaAs substrate.

Fig. 1



have a semiconductor laser according to the present invention emit light in the wavelength range from 1.2 to 1.35 μm.

[0023] From the newly gained knowledge of the inventors, in the optimum range of 0.2 to 0.4 mole of Sb content, the quantum well layer has a composition modulated structure in which there is alternation between two types of GaAsSb compositions having different Sb compositions, for example between $GaAs_{0.6}Sb_{0.4}$ and $GaAs_{0.8}Sb_{0.2}$, in a direction that is different from the thickness direction, this typically being in a direction that is approximately perpendicular to the thickness direction.

[0024] By virtue of this composition modulated structure, there is further encouragement of the narrowing of the band gap, making it possible to achieve long-wavelength light emission with an even smaller amount of Sb.

[0025] Fig. 7 shows as an example of the above-noted composition modulated structure, a trace of an electron microscope photograph of a quantum well layer 702 having a composition of $GaAs_{0.7}Sb_{0.3}$.

[0026] In this example, the quantum well layer 702, which is epitaxially joined to the (100) surface of the GaAs light waveguide layers 701 and 703, has a structure that alternates between a region 711 having a composition of $GaAs_{0.6}Sb_{0.4}$ and a region 712 having a composition of $GaAs_{0.8}Sb_{0.2}$.

[0027] An example of a semiconductor laser according to the present invention will be described in further detail below, with reference being made to relevant drawings.

[0028] A semiconductor laser according to the present invention is suitable for use in virtually any type of edge-emitting or surface-emitting semiconductor laser, in which case it is possible to use a substrate made of GaAs.

[0029] A typical edge-emitting or surface-emitting semiconductor laser is a so-called double hetero-junction semiconductor laser in which the action region that is formed between a first light waveguide layer and a second light waveguide layer having a different electrical conductivity, these each being formed on a substrate of GaAs or the like, and a typical edge-emitting semiconductor laser is a buried type of semiconductor laser, Fig. 1 showing as one example of a semiconductor laser of double-channel planar buried hetero-junction (DCPBH) structure.

[0030] That is, in the semiconductor laser that is shown in Fig. 1, an active layer 104 that forms an active region is provided on, for example, a GaAs substrate102, with an n-type GaAs buffer layer therebetween, a p-type GaAs clad layer 105, a p-type GaAs block layer 106, an n-type GaAs layer 107, a p-type GaAs buried layer 108, and a p-type GaAs cap layer 109 being laminated onto the active layer 104 in that sequence, a central stripe part of the active layer 104 being surrounded by downward hanging parts 111 of the GaAs blocking layer 106. In this drawing, the reference numerals 101 and 110 denote electrodes.

[0031] The semiconductor laser shown in Fig. 2 is called a ridge waveguide type semiconductor laser.

[0032] As shown in this drawing, an active layer 203 that serves as an active region and a p-type light waveguide layer 204 are laminated in this sequence onto an n-type light waveguide layer 202.

[0033] Additionally, a high-concentration p-type doped contact layer 205 is formed on the p-type light waveguide 204 and, to achieve current pinching, two trench structures 210 are provided, and an insulation film 206 is formed so that current does not flow except in a ridge 209 that is sandwiched between these trenches.

[0034] In this drawing, the reference numerals 207 and 208 denote a p-type and an n-type contact metal film, respectively, 201 is a voltage source, and when a voltage is applied across the metal films 207 and 208, current flows only in the ridge part 209, with light being emitted from the active layer 203.

[0035] The light that is emitted is guided in the ridge stripe direction by the upper and lower light waveguide layers.

[0036] The end of the stripe is an open wall surface, at which part of the light is reflected so that overall optical resonance is established. In this manner, laser oscillations occur at above a threshold current density.

[0037] Fig. 3 shows a semiconductor laser of the surface-emitting type, in which for example on a GaAs substrate 301 are formed a multilayer structure n-type and p-type distributed Bragg reflector (DBR) formed by GaAs/AlAs films 302 and 304, between which is formed an active layer 303, with spacers 307 therebetween, which will serve as an active region.

[0038] In this drawing, the reference numerals 305 and 306 denote an anode and a cathode, respectively. In the examples shown in Fig. 1 through Fig. 3, the GaAs film or the like that is formed on a GaAs substrate can be formed as an epitaxially grown layer that is epitaxially joined to, for example, the GaAs (100) surface.

[0039] In the present invention, in the case in which a quantum well layer made of GaAsSb is provide in an active region, because it is sufficient to provide a quantum well structure part that includes a quantum well in part or all of the active region, the present invention encompasses the case in which there is also an active region that includes a quantum well structure that does not include, for example, a quantum well layer other than a quantum layer made of GaAsSb or a quantum well layer made of GaAsSb.

[0040] In this case, it is desirable that, in a quantum well structure that includes a quantum well ride of GaAsSb, a barrier layer made of a material having a large band gap be provided on both sides of the quantum well layer.

[0041] For example, in the case in which a hetero-junction boundary is formed using GaAsSb and GaAs, the difference between the conduction band energies of

Fig. 8 is a drawing of the band structure of a semiconductor laser manufactured as an embodiment of the present invention.

Fig. 9 is a drawing of the band structure of a semiconductor laser manufactured as an embodiment of the present invention.

Fig. 10 is a drawing of the band structure of a semiconductor laser manufactured as an embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0057] Embodiments of a semiconductor laser according to the present invention are described in detail below, these embodiments achieving the above-noted object of the present invention, but not to be construed as placing any restriction on the present invention.

[0058] The first embodiment of the present invention is in the form of a so-called ridge waveguide semiconductor laser, the method of manufacture of which is shown in Fig. 2.

[0059] The epitaxial growth of layers onto a GaAs substrate is done using a gas source molecular beam epitaxy method.

[0060] As shown in Fig. 5, first a silicon doped (3×10^{18} cm^{-3}) GaAs buffer layer 502 and then a silicon doped (1×10^{18} cm^{-3}) $Al_{0.4}Ga_{0.6}As$ layer 503, having a thickness of 1.5 µm are laminated onto a silicon doped (3×10^{18} cm^{-3}) GaAs substrate, so as to form an n-type light waveguide 511.

[0061] Next, an undoped $Al_{0.2}Ga_{0.8}As$ layer 506 is laminated to a thickness of 40 nanometers, after which period laminations are done of a 10-nanometer undoped GaAs barrier layer 505 and an 8-nanometer strained $GaAs_{0.7}Sb_{0.3}$ quantum well layer 504, after which a 40-nanometer undoped $Al_{0.2}Ga_{0.8}As$ layer 506 is laminated, thereby forming an active layer 512 that serves as an active region.

[0062] Additionally, onto this active layer 512, a 1.5 µm Be-doped (1×10^{18} cm^{-3}) $Al_{0.4}Ga_{0.6}As$ layer 507 is laminated so as to form a p-type light waveguide 513, and finally a 50-nanometer Be-doped (1×10^{19} cm^{-3}) GaAs contact layer 508 is formed as a p-type contact layer.

[0063] In a ridge stripe laser such as shown in Fig. 2, lithography and chemical etching are first used to form trenches 210 on both sides of the ridge strip.

[0064] In the area other than the ridge strip upper surface, a 200-nanometer-thick SiO_2 insulation film 206 is formed, so that it is possible to insert current in only the ridge stripe part.

[0065] Then, a Ti/Au p-type metal contact layer 207 and a Ti/Au n-type metal contact layer 208 are formed and alloyed. The oscillation wavelength of this semiconductor laser at room temperature was 1.29 µm, and the threshold current density was 1.0 kA/cm^2.

[0066] The characteristic temperature from room temperature to 85°C was approximately 80K.

[0067] Fig. 8 shows the band structure of the first embodiment of the present invention obtained as described above.

[0068] In this drawing, the reference numerals 801, 802, 803, and 804 denote the bands of the GaAs substrate 501, the GaAs buffer layer 502, the $Al_{0.4}Ga_{0.5}As$ layer 503, and the undoped $Al_{0.2}Ga_{0.8}As$ layer 506, respectively, 805 and 806 are the bands of the undoped GaAs barrier layer 505 and the strained $GaAs_{0.7}Sb_{0.3}$ quantum well layer 504, respectively, and 807, 808, and 809 are the bands of the undoped $Al_{0.2}Ga_{0.8}As$ layer 506', the $Al_{0.4}Ga_{0.6}As$ layer 507, and the p-type GaAs contact layer 508, respectively.

[0069] In this embodiment, a quantum well layer structure is formed by the alternating laminations of the GaAs barrier layer 505 and the distorted GaAsSb quantum well layer 504.

[0070] A feature of the present invention, as shown in Fig. 8, is the use of an Sb-based material as the light-emitting layer, and the achievement of light emission at a wavelength of 1.3 µm or greater on a GaAs substrate.

[0071] Upon observation of the [- 110] cross-section of the structure of this GaAsSb layer using a transmission electron microscope, a so-called composition modulation, in which the Sb composition changed with a period of approximately 1 nanometer in a direction perpendicular to the lamination direction, was observed.

[0072] Fig. 9 shows the band structure of the second embodiment of the present invention, this being for the case in which a semiconductor laser provided with the same type of active region structure as in Fig. 5 is fabricated.

[0073] In this embodiment, periodic lamination is done of three layers, these being a 40-nanometer undoped $Al_{0.2}Ga_{0.8}As$ layer 506, a 10-nanometer undoped AlGaAs barrier layer 505, and an 8-nanometer distorted $GaAs_{0.7}Sb_{0.3}$ quantum well layer 504.

[0074] Over this periodic lamination is further laminated a 50-nanometer undoped $Al_{0.2}Ga_{0.8}As$ layer 506' so as to form an active layer 512. In Fig. 9, the reference numerals 901, 902, 903, and 904 denote the bands of the GaAs substrate 501, the GaAs buffer layer 502, the $Al_{0.4}Ga_{0.6}As$ layer 503, and the undoped $Al_{0.2}Ga_{0.8}As$ layer 506, respectively, 905 and 906 are the bands of the undoped AlGaAs barrier layer 505 and the strained $GaAs_{0.7}Sb_{0.3}$ quantum well layer 504, respectively, and 907, 908, and 909 are the bands of the undoped $Al_{0.2}Ga_{0.8}As$ layer 506', the $Al_{0.4}Ga_{0.6}As$ layer 507, and the p-type contact layer 508, respectively.

[0075] By using an $Al_{0.2}Ga_{0.8}As$ layer as the barrier layer 505 of the quantum well layer structure, it is possible to make the discontinuity in the conduction band approximately 200 meV, thereby enabling achievement of sufficient electron confinement.

[0076] When a semiconductor laser having this type of active region was applied to a ridge waveguide type semiconductor laser such as in the first embodiment, it

2. A semiconductor laser according to claim 1, wherein the amount of Sb contained in said GaAsSb is in the range from 0.2 to 0.4 moles with respect to a total 1 mole amount of As and Sb.

3. A semiconductor laser according to claim 2, wherein a plurality of said GaAsSb layers are adjacently arranged to each other.

4. A semiconductor laser according to claim 3, wherein said quantum well layer exhibits composition modulation, in which the Sb content of said GaAsSb alternates in a direction that is different from the thickness direction thereof.

5. A semiconductor laser according to claim 4, wherein said quantum well layer exhibits composition modulation, in which the Sb content of said GaAsSb alternates in a direction that is nearly perpendicular to the thickness direction thereof.

6. A semiconductor laser according to claim 3, wherein said Sb content of at least one of said GaAsSb layers is different from that of the remaining said GaAsSb layers.

7. A semiconductor laser according to claim 1, wherein said active region is provided on a GaAs substrate.

8. A semiconductor laser according to claim 7, wherein said active region is provided between a first light waveguide layer having a first conductivity and a second light waveguide layer having a second conductivity that is different from said first conductivity.

9. A semiconductor laser according to any of claim 1 through claim 8, comprising a quantum well structure part that includes said quantum well layer in a least part of said active region.

10. A semiconductor laser according to claim 9, comprising a barrier layer that has a band gap that is larger than GaAs, said barrier layer being disposed on both sides of said quantum well layer.

11. A semiconductor laser according to claim 10, wherein the material used to form said barrier layer is selected from the group consisting of AlGaAs, GaAsP, AlGaAsP, GaInP and AlGaInP.

12. A semiconductor laser according to claim 10, wherein the lattice constant of said barrier layer is smaller than the lattice constant of GaAs.

13. A semiconductor laser according to claim 12, wherein the material used to form said barrier layer is selected from the group consisting of GaAsP, AlGaAsP, GaInP, and AlGaInP.

14. A semiconductor laser according to claim 10, further comprising, between said quantum well layer and said barrier layer, an intermediate layer that is made of a material that has a band edge energy that is intermediate between the band edge energy of said quantum well layer and the band edge energy of said barrier layer that forms said quantum well layer.

15. A semiconductor laser according to claim 13, wherein the material that forms said intermediate layer is selected from the group that consists of GaAs, GaAsP, and GaAsN.

16. A semiconductor laser according to claim 14, wherein the lattice constant of the material that forms said intermediate layer is smaller than the lattice constant of GaAs.

17. A semiconductor laser according to claim 16, wherein the material that forms said intermediate layer is selected from the group that consists of GaAsN and GaAsP.

Fig. 3

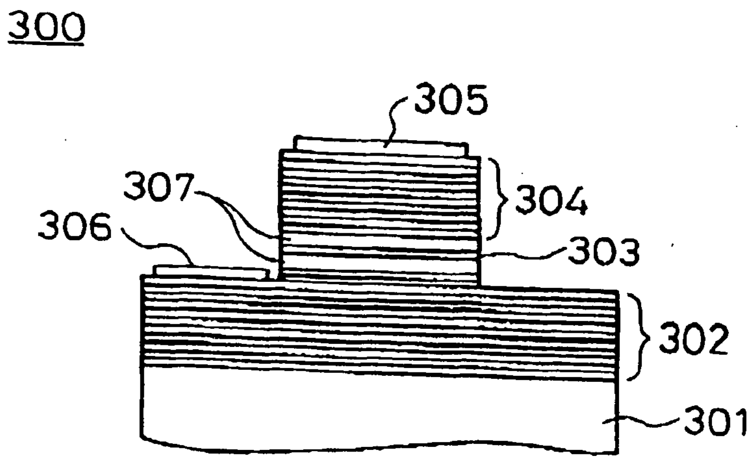

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Fig. 4

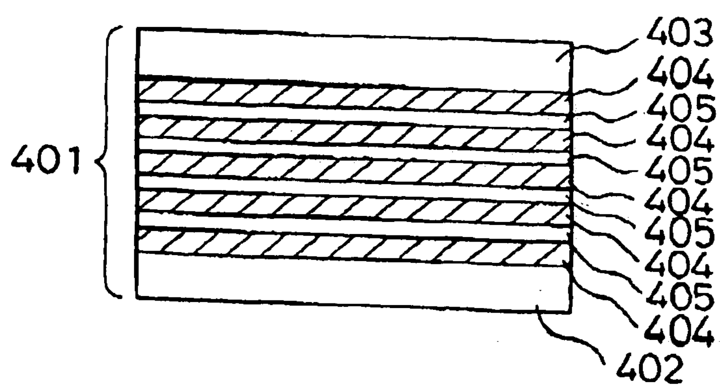
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Fig. 7

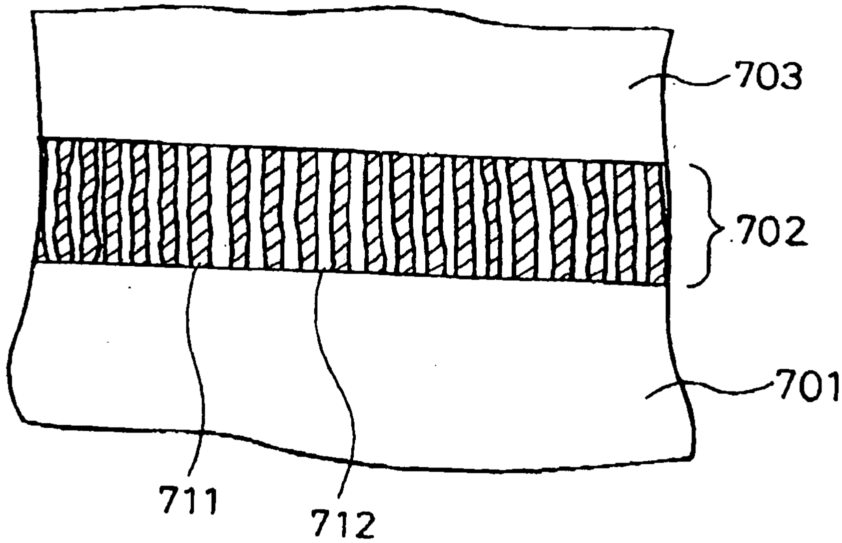
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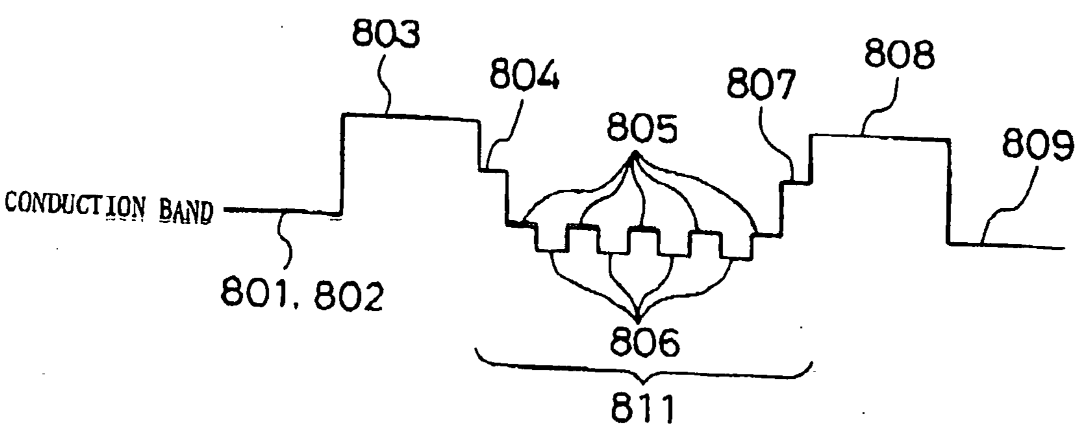
Fig. 8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Application Number
EP 99 11 1787

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	22 July 1999	Gnugesser, H

CATEGORY OF CITED DOCUMENTS

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